

FLEX-Fluorescence 2026 Workshop

03 – 06 March | Bonn University, Germany



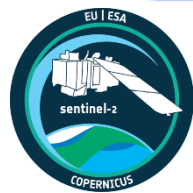
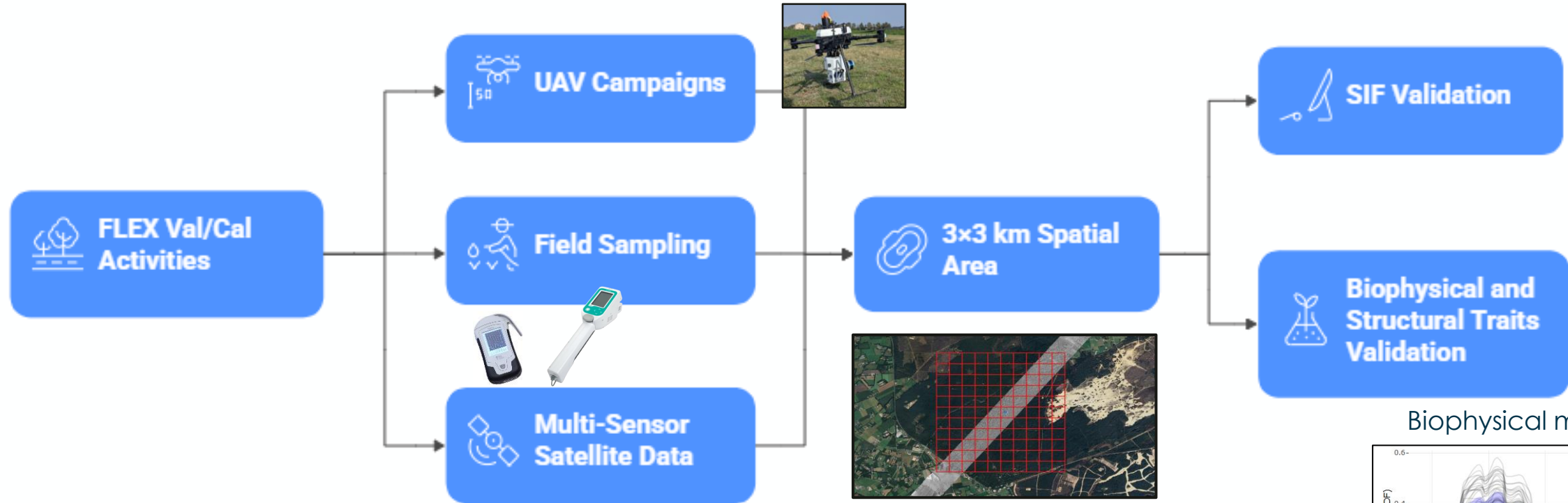
FLORA – FLEX Leaf Observation and Retrieval via Hybrid Approaches: A Multi-Sensor Framework for Calibration and Validation of FLEX L2B/L2C Products

Carlos Camino (1) on behalf of FLORA team

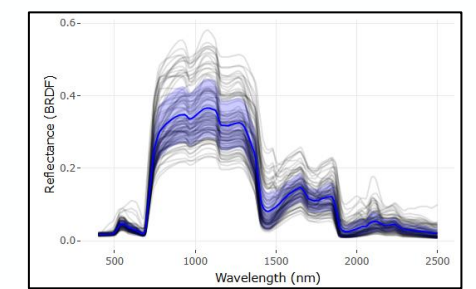
FLORA: FLEX Leaf Observation and Retrieval via hybrid Approaches



The project validates FLEX Level-2C vegetation products (LCC, LAI, LCARC, and fPAR) and Level-2B SIF through a multi-platform strategy involving UAV campaigns, field sampling, radiative transfer modelling, and multi-sensor satellite data.



Biophysical models



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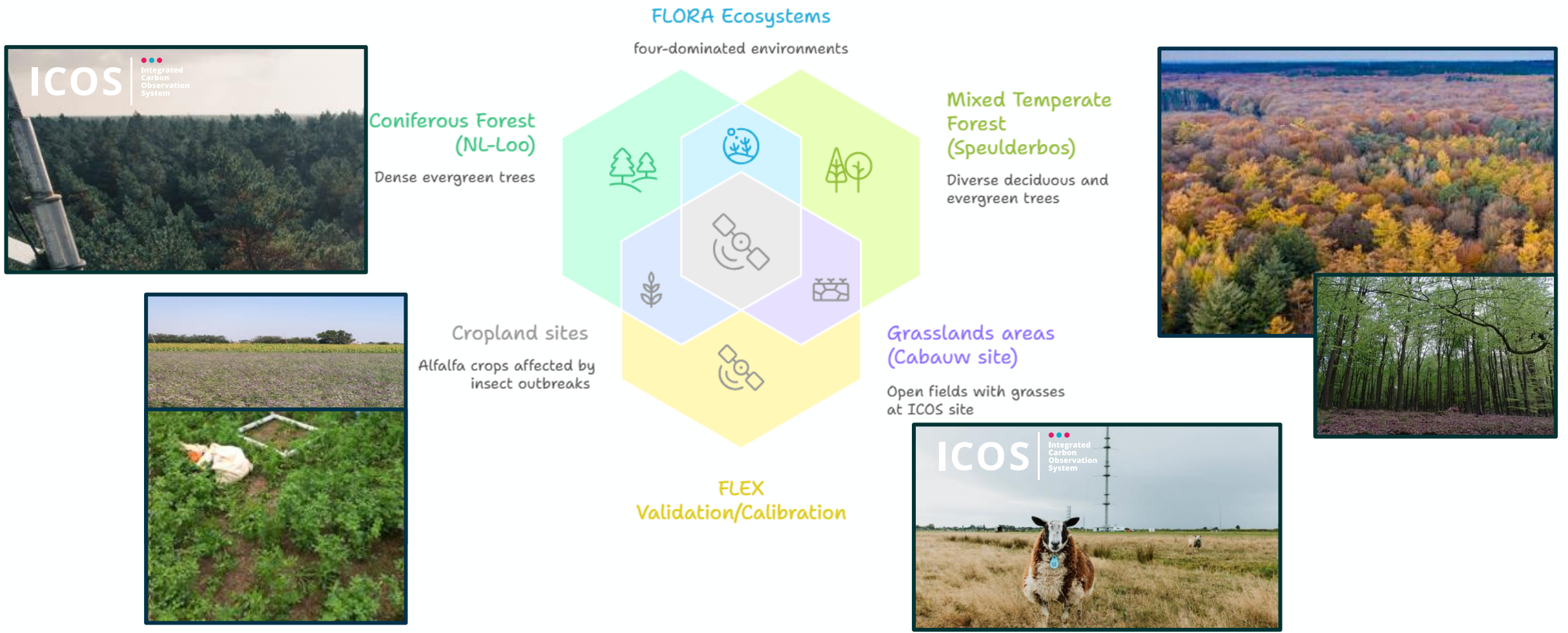
Subtitle: Calibration and Validation of FLEX Level-2 Vegetation Products Using UAV Earth Observation, Radiative Transfer Models, and Ground-Based Observations in ICOS Forest and Grassland Ecosystems

Consortium



FLORA: FLEX Leaf Observation and Retrieval via hybrid Approaches

FLORA is designed around four contrasting European ecosystems



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In the Netherlands, **FLORA** includes the ICOS Scots pine forest at **NL-Loobos** with continuous eddy covariance flux measurements, the mixed temperate forest at **Speulderbos**, and the managed grasslands at the **ICOS Cabauw** site, all contributing to spectral scaling at FLEX spatial scales.



Netherlands

NL-Loobos



Speulderbos forest close to NL-Loobos



NL-Cabauw



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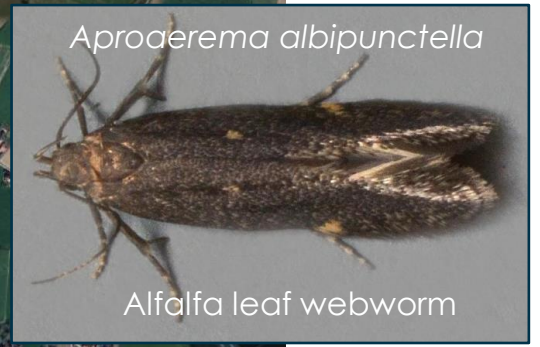


In Italy, **alfalfa fields** in the Lombardy region affected by *Aproaerema albipunctella* serve as dedicated cropland test sites. These activities are funded within the ESA **HYDRA-EO** project framework.”



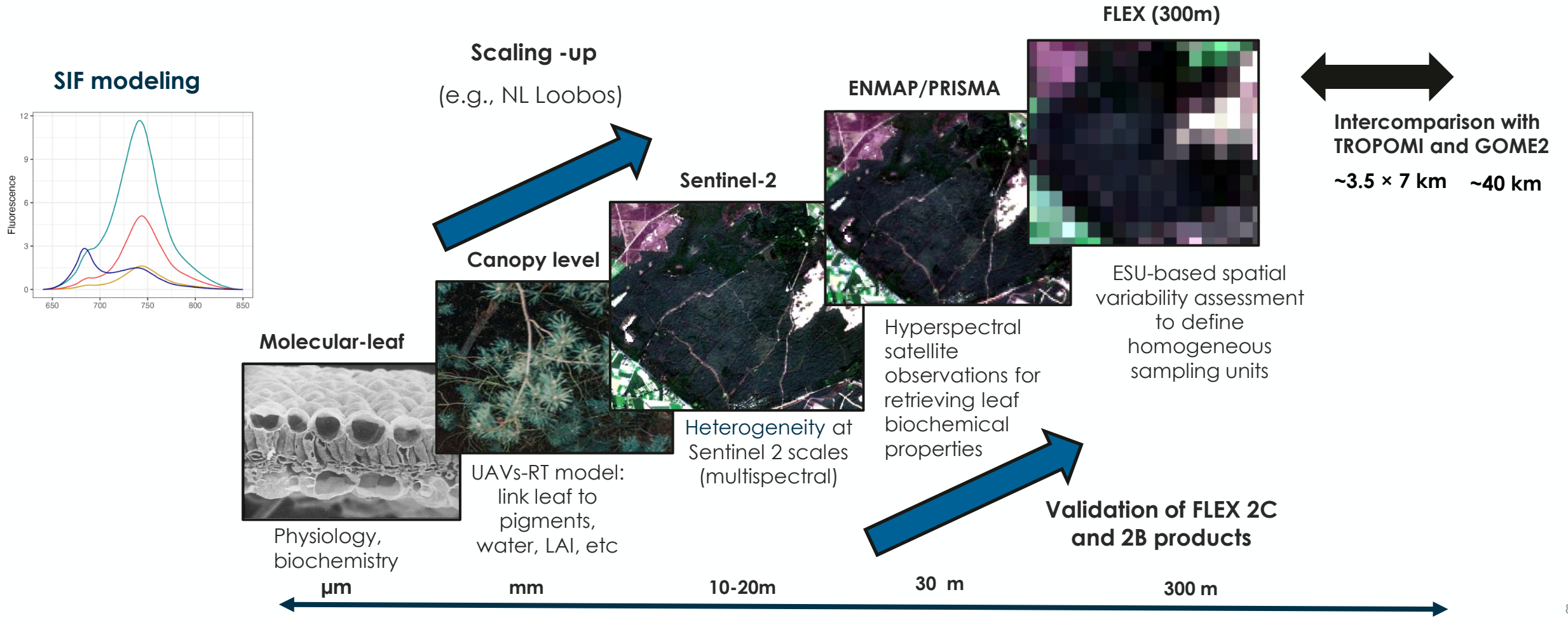
Italy

Alfalfa sites affected by **biotic** stressor



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To validate FLEX products, we need a multi-scale validation strategy, moving from leaf and canopy measurements to satellite observations and ultimately to FLEX 300-meter resolution



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Generation of **Elementary Sampling Units (ESUs)** to quantify the spatial variability of key **VGs** (e.g., NDRE, Red-edge index, PRI), and main **inverted plant traits** to identify homogeneous zones within each 300 m pixel, thereby supporting statistically robust field design and multi-scale scaling.

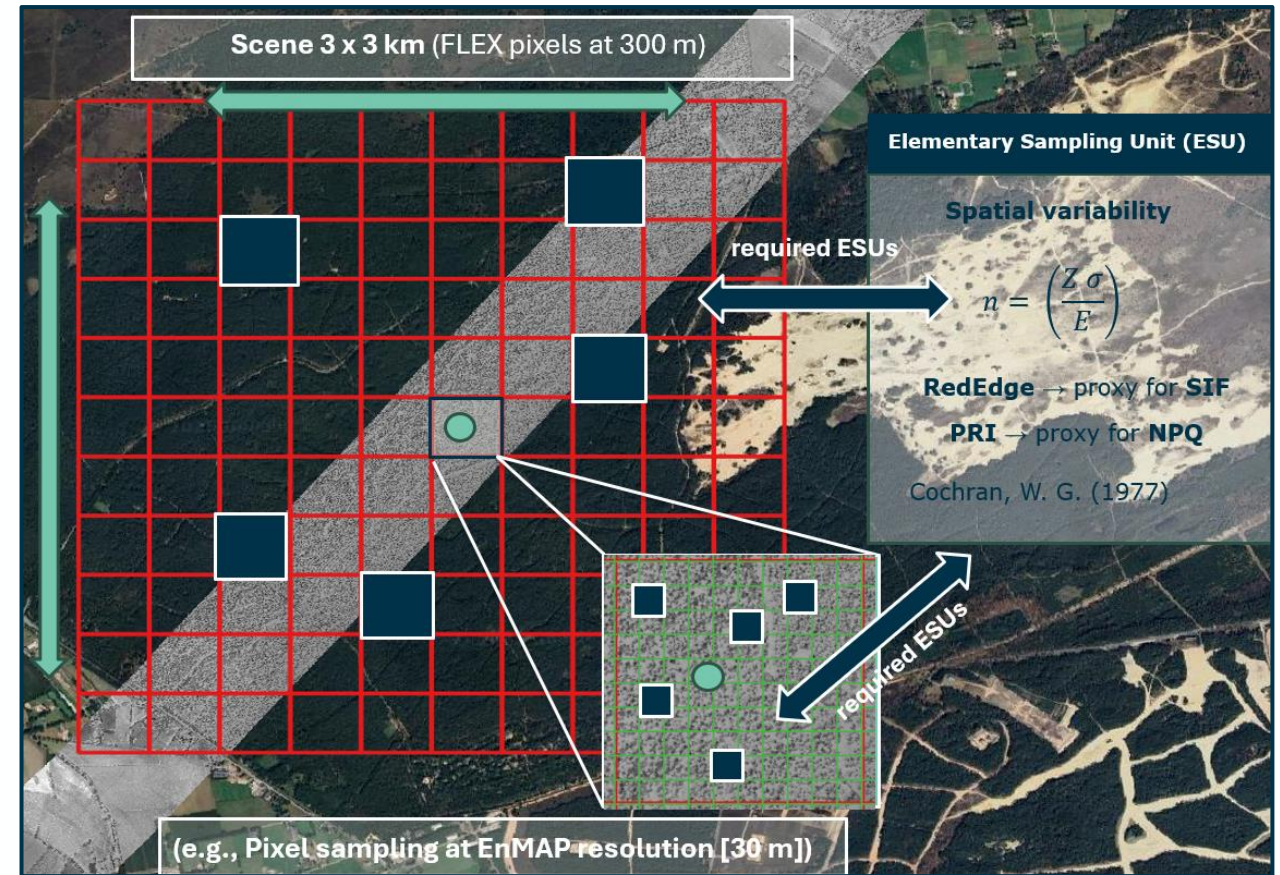
NL-Loobos



NL-Cabauw



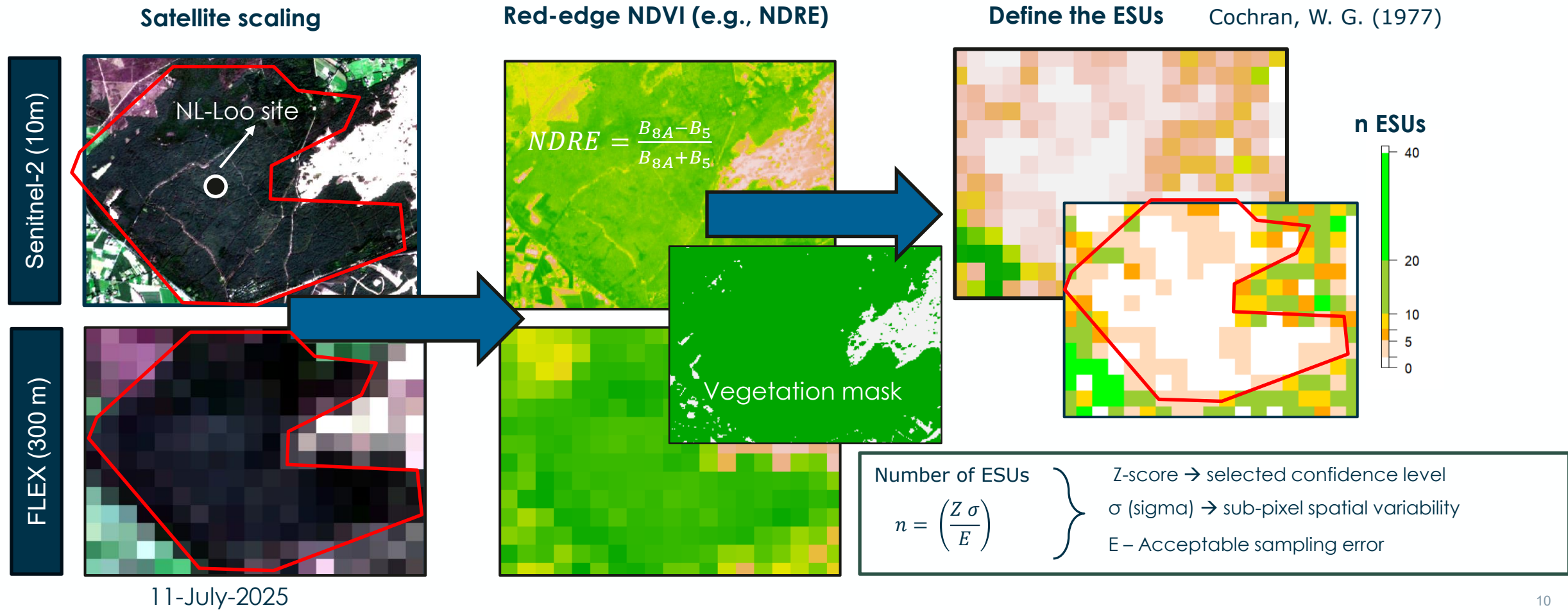
(e.g., HyPlant flight conducted in summer 2024 at NL-Loobos site)



Cochran sampling method to determine the ESUs

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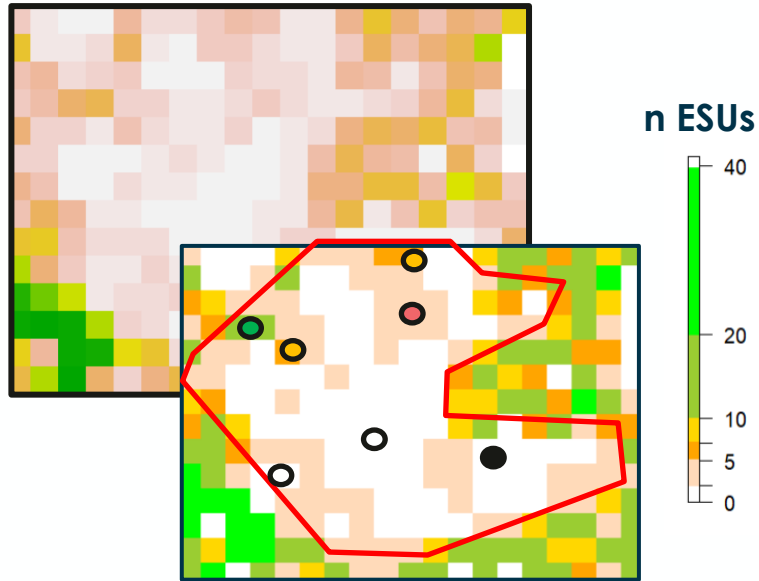
Generation of Elementary Sampling Units (ESUs) supports statistically robust field sampling design and multi-scale upscaling to FLEX spatial resolution.



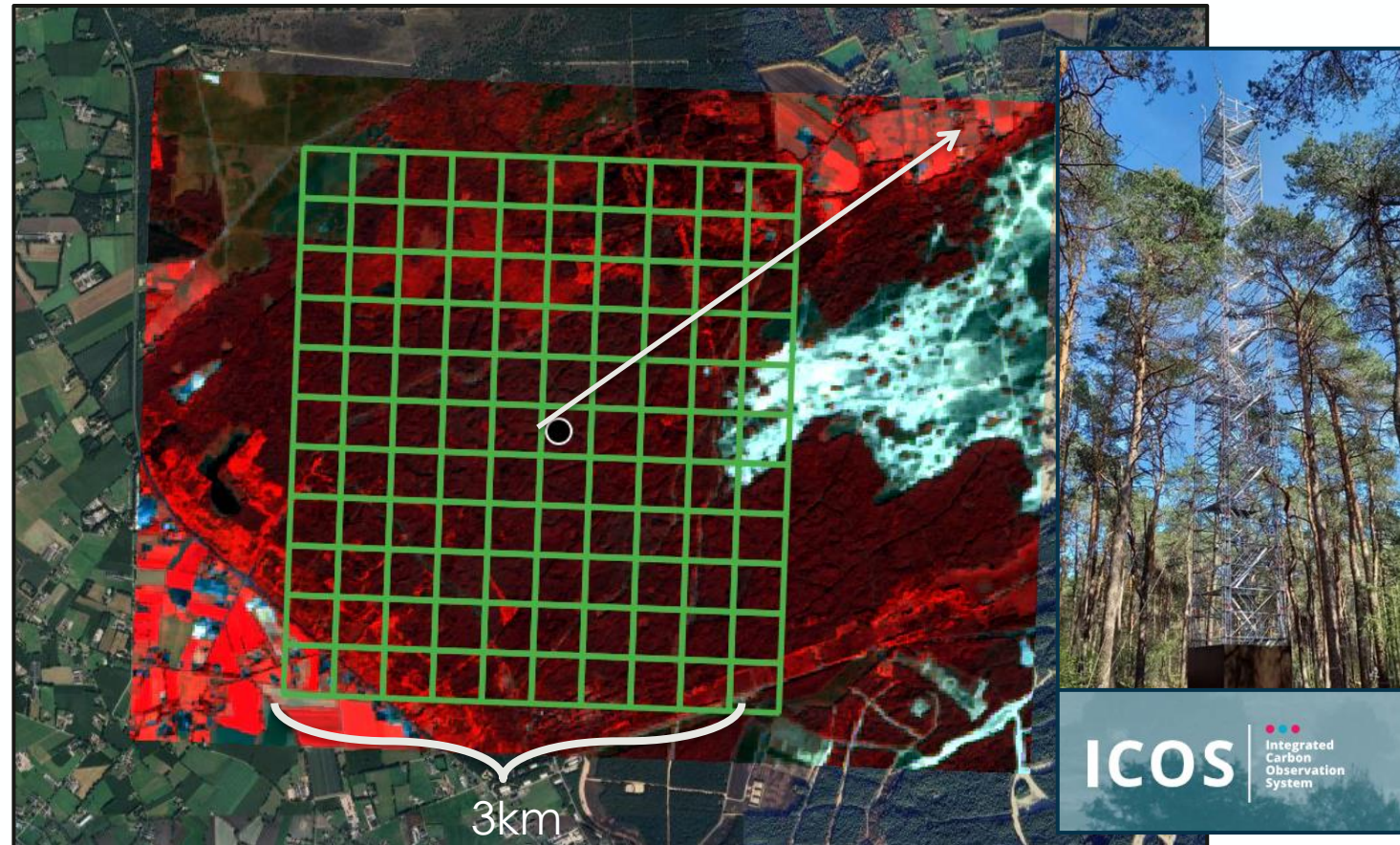
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ESUs identify homogeneous FLEX pixels for aerial- field campaigns and highlight heterogeneous areas requiring careful scaling, where scaling uncertainty increases.

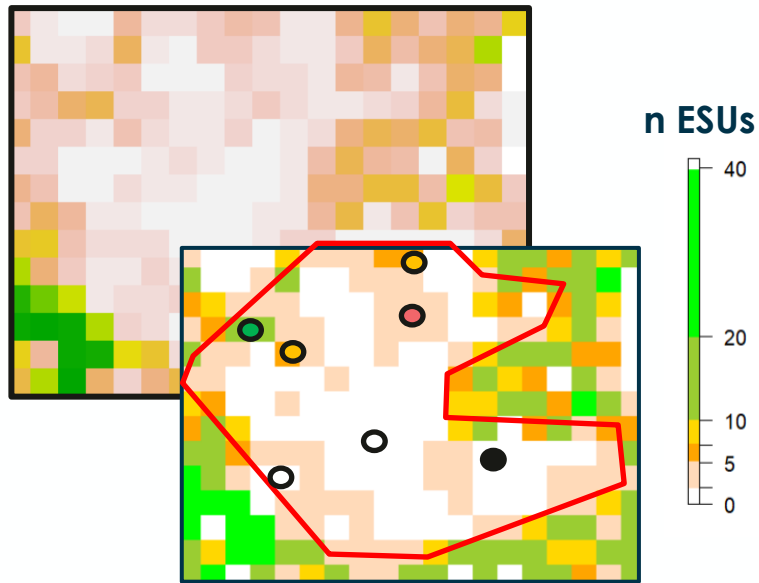


[e.g., Min n field data required for chlorophyll validation]



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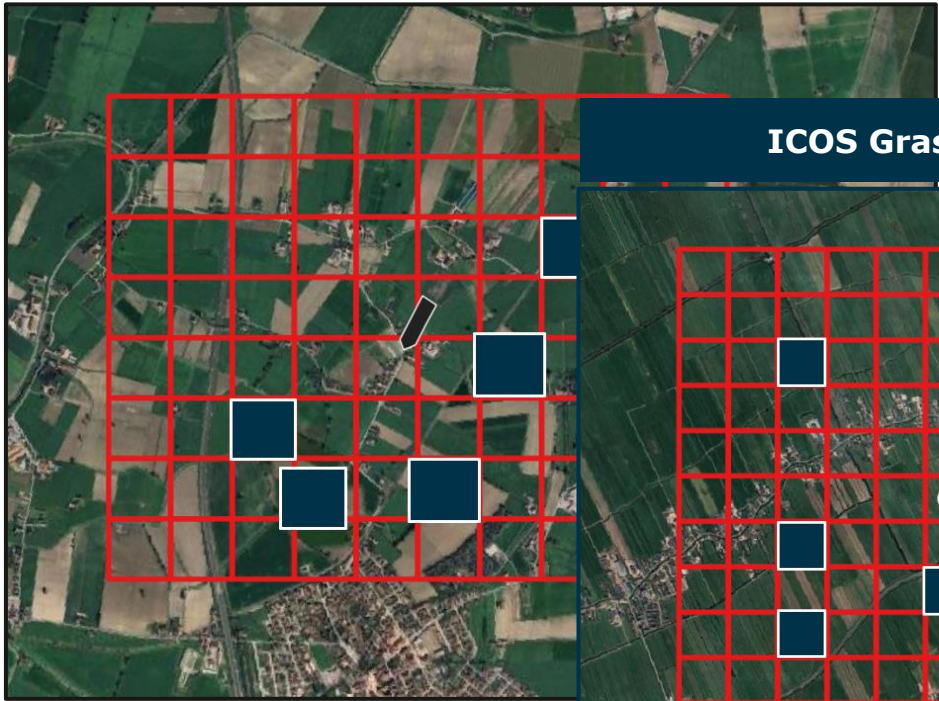
Areas for aerial campaigns

ICOS Integrated Carbon Observation System

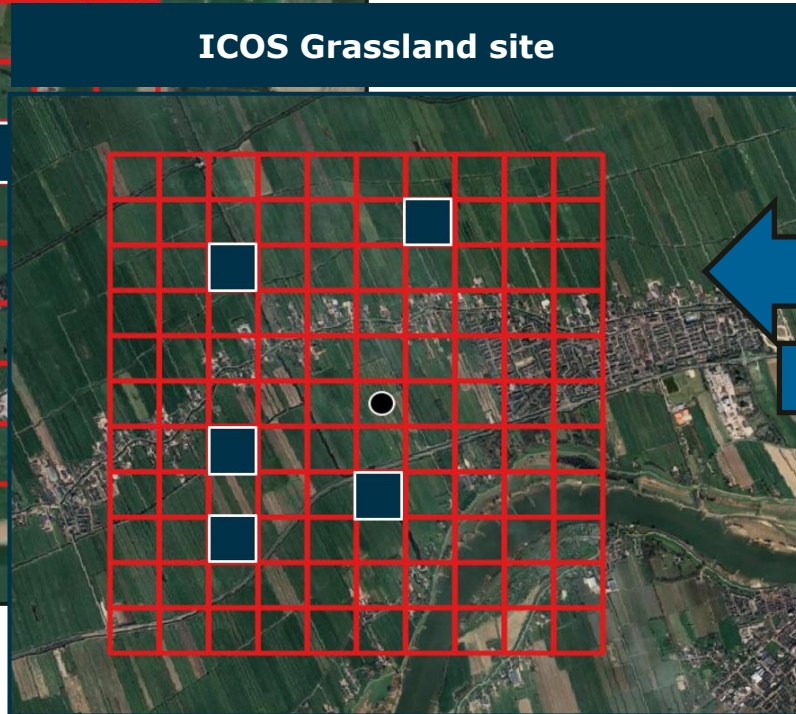
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These ESUs become particularly important when working in highly heterogeneous sites

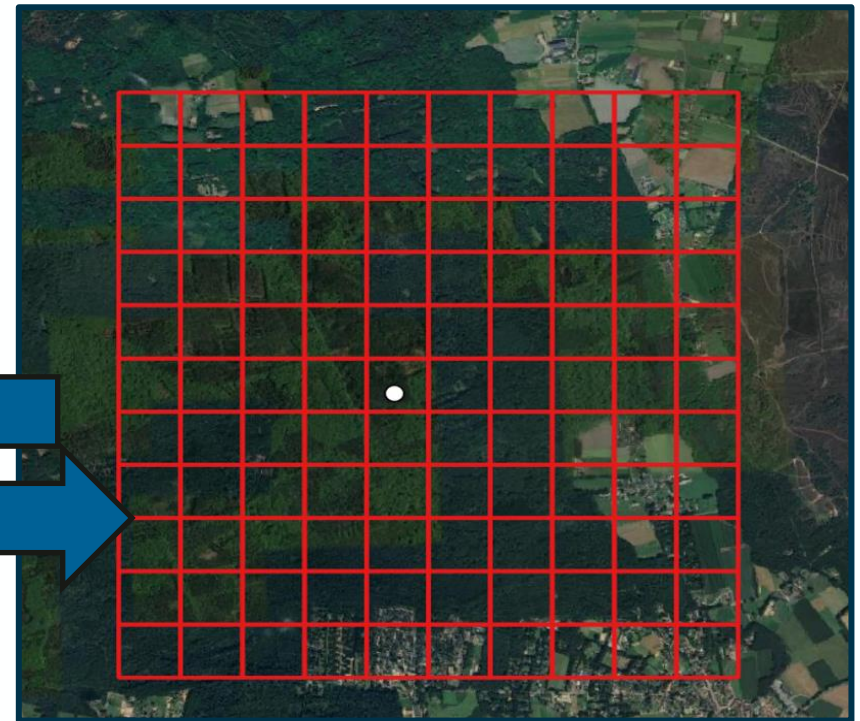
Alfalfa sites



ICOS Grassland site



Speulderbos Forest



Compared to mixed or more homogeneous areas

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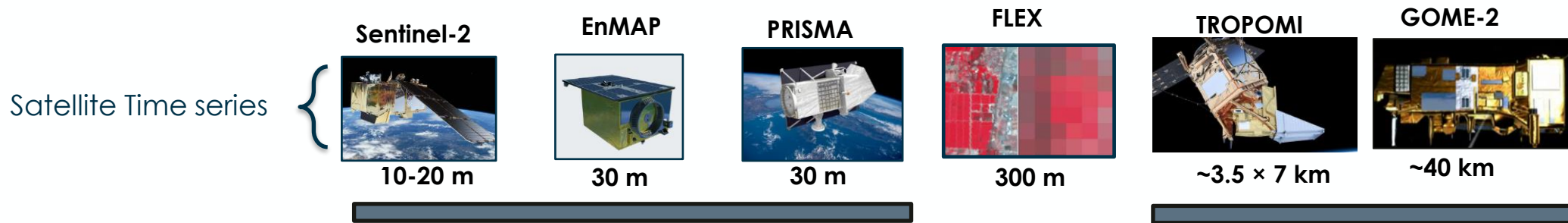
Aerial campaign when FLEX images will be available on the sites



- UAV-Headwall Hyperspectral (400 – 1000 nm, < 1m)
- UAV-Headwall Hyperspectral Co-Aligned (400 – 2500 nm, < 1m)
- High-resolution Thermal cameras
- FluorSpec point sensor for SIF retrievals

} LIDAR system

The aerial campaign is complemented by satellite observations to quantify landscape heterogeneity across spatial scales.



Validation FLEX Level-2C vegetation products (LCC, LAI, LCARC, and fPAR)

Validation FLEX Level-2B SIF

Field campaign on the sites based on the ESU sampling design (Spring Summer 2027)

Non-Destructive leaf samples

Leaf physiological and canopy measurements



Destructive leaf samples

Biochemical analysis of leaf pigments (chlorophylls, carotenoids, anthocyanins), leaf water content and dry matter content to assess photosynthesis and stress responses, as well as macro- and micro-nutrients (N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu, B).

Field campaign on the sites based on the ESU sampling design (Spring Summer 2027)

SIF measurements

Piccolo-Doppio System (continuous canopy-level SIF monitoring)

FLOX systems (high-frequency SIF and reflectance measurements)



Proximal sensing: Spectroradiometer Spectra Evolution (400 – 2500 nm)



Leaf and canopy reflectance measurements

Radiometric calibration using reference panels

Thanks for your attention!!!



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Subtitle: Calibration and Validation of FLEX Level-2 Vegetation Products Using UAV Earth Observation, Radiative Transfer Models, and Ground-Based Observations in ICOS Forest and Grassland Ecosystems

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